2)

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 071 221 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
24.01.2001 Bulletin 2001/04

(51) Int Cl.7: H04B 1/16, H04H 1/00

(21) Application number: 99305867.6

(22) Date of filing: 23.07.1999

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(71) Applicant: MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.
Kadoma-shi, Osaka 571-8501 (JP)

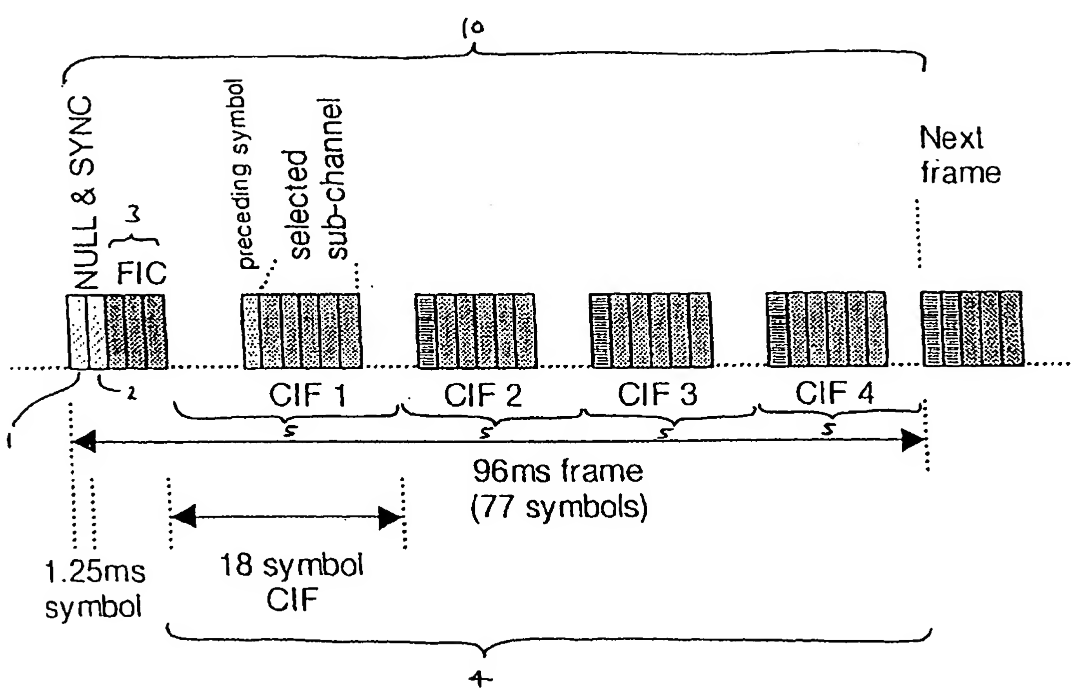
(72) Inventor: Wong, Danny
Wokingham, Berkshire, RG41 3BW (GB)

(74) Representative: Dawson, Elizabeth Ann et al
A.A. Thornton & Co.
235 High Holborn
London WC1V 7LE (GB)

(54) Method to reduce the power consumption of radio receiver

(57) A method for reducing the power consumption of a radio receiver, and in particular a digital audio broadcast receiver, is described, in which the RF tuner of the receiver is powered up during portions of the received signal which contain information relating to the location of data within the signal. The tuner is then also powered up at various other times in response to this information, in order to allow the reception and demodulation only of selected data. In this way, it is possible to power down the tuner during some portions of the signal, thereby reducing power consumption.

FIG. 1



EP 1 071 221 A1

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] This invention relates to a method to reduce the power consumption of a radio receiver, and in particular a Digital Audio Broadcast radio receiver.

[0002] The European Digital Audio Broadcasting (DAB) standard (European Broadcast Union, Radio broadcast system: Digital audio broadcasting to mobile, portable and fixed receivers, ETS 300 401, revised July 1997) is growing in acceptance throughout the world as the replacement for conventional AM/FM radio broadcasting. A DAB transmission is based on Orthogonal Frequency Division Multiplex (OFDM) modulation. Instead of transmitting on a single carrier frequency, OFDM uses many carrier frequencies simultaneously. This results in a broadband signal with a low symbol (baud) rate. OFDM offers two clear advantages in a mobile reception environment:

1. When a few carrier frequencies are corrupted, they only represent a small proportion of the transmission. With forward error correction coding, very few errors can occur after decoding.
2. As the symbol duration is long, a majority of the reflected signals due to multipath propagation or multiple transmitters may constructively interfere and strengthen the main signal.

[0003] In the time domain, the DAB signal is delivered as frames that are made up of consecutive OFDM symbols. The number of OFDM symbols to make up a frame depends on the DAB transmission mode, i.e. the combination of the number of carrier frequencies and symbol duration. The modes specified by the DAB standard are given in the following table:

DAB Mode	Number of carriers	Symbol duration (approximate)	Symbols per frame
I	1536	1.25ms	77
II	384	0.31ms	77
III	192	0.16ms	154
IV	768	0.62ms	77

[0004] Irrespective of the transmission mode, all DAB frames have a common format. At the start, there is a synchronisation channel, within which there are the NULL and Phase Reference (denoted by SYNC) symbols for both coarse and fine time/frequency synchronisation. Then follows the Fast Information Channel (FIC) which holds a continuously updated directory of the contents of the rest of the frame, the Main Service Channel (MSC). The MSC forms the majority of the frame and it contains the payload of audio and data services occupying sub-channels. The organisation of the MSC is such that the information bits of each sub-channel would map onto a number of consecutive OFDM symbols. The MSC can be further divided into Common Interleaved Frames (CIF). An example DAB frame in mode I is given in Fig. 1.

[0005] An audio sub-channel usually occupies less than 20% of the OFDM symbols in a typical frame. For example, the BBC's DAB transmission carries at least six audio sub-channels.

[0006] The architecture of a simplified DAB receiver 20, which might be used to recover the audio and data services in a DAB transmission, is shown in Fig. 2.

[0007] The RF tuner 21 down-converts the broadcast signal so that it can be sampled by the Analogue-to-Digital Converter (ADC) 22. Individual frequency components within each symbol of the digitised broadband signal are extracted using Fast Fourier Transform (FFT) in the FFT processor 23. These resolved frequency components are then decoded in three steps to remove the channel protection coding, which consists of Differential Quadrature Phase Shift Keying (DQPSK), time-and-frequency interleaving, and convolutional coding. The decoding correspondingly takes place in the DQPSK demodulator 24, deinterleaver 25 and Viterbi decoder 26. For audio sub-channels, the data is further decompressed with a MPEG audio decoder 27.

[0008] In many DAB receiver implementations, a number of the functional blocks shown are integrated on the same integrated circuit. However, invariably the RF tuner 21 remains an external block. Typically it is powered continuously and may consume up to 3W. Comparatively speaking, the rest of the DAB receiver circuitry (audio amplifier excepted) consumes less than 1W of power.

[0009] US 5392457 discloses a battery saving method for a communication receiver, in which the power supply to the receiver is suspended when it is detected that the address portion of a coded message signal does not correspond to the designated address of the receiver. By this method, the remainder of the frame is not received, and power is saved when a message is not intended for a particular receiver. However, in DAB receivers each frame will contain data relevant to the sub-channels selected by the user, even though this relevant data may form only a small portion

of the frame. In addition, there exists the complication that the user may select any of various sub-channels, and that the location of a given sub-channel within the frame may change.

[0010] One aspect of the present invention provides a method for reducing the power consumption of a radio receiver comprising a tuner for receiving a modulated signal and means for demodulating the received signal, the signal being transmitted in the form of transmission frames, each frame comprising a data portion and a configuration portion which contains information regarding the location of data within the data portion,

wherein power is supplied to the tuner to allow reception of the configuration portion of each frame, and the supply of power to the tuner is modulated in response to the information contained in the configuration portion to enable reception of selected data within the data portion of the frame.

[0011] In a preferred embodiment, the tuner is completely or partially powered down during at least a part of the data portion which does not contain selected data, and full power is supplied to the tuner during the remainder of each frame. In other words, during portions of the frame which do not contain required information, power may be conserved by reducing the supply of power to the tuner, either fully or partially.

[0012] Power is preferably additionally supplied to the tuner for a predetermined period preceding and/or following portions of the frame containing the selected data. This period may be a "guard period" allowing for the transient settling of the tuner.

[0013] When used with a DAB transmission as described previously, the configuration portion may comprise the FIC and the NULL and SYNC symbols. The data portion may correspond to the MSC.

[0014] Another aspect of the invention provides a radio receiver for receiving a modulated signal transmitted in the form of transmission frames, each frame comprising a data portion and a configuration portion which contains information regarding the location of data within the data portion, the receiver comprising:

a tuner for receiving the modulated signal,
means for demodulating the received signal,
means for supplying power to the tuner to allow reception of the configuration portion of each frame, and
means for modulating the supply of power to the tuner in response to the information contained in the configuration portion of each frame, to enable reception of selected data within the data portion of the frame.

[0015] Additional preferred features of the invention are described in the annexed sub-claims 3 to 14 and 16 to 21.

[0016] A specific embodiment of the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 shows the composition of typical DAB frame; and
Figure 2 shows schematically the architecture of a DAB receiver.

[0017] As described previously, the DAB frame illustrated in Figure 1 is in the form of a mode I frame 10 in accordance with the European Broadcast Union (EBU) DAB standard. The frame consists of 77 consecutive symbols, comprising a NULL symbol 1, a Phase Reference symbol (SYNC) 2, the FIC 3 and the MSC 4. Other transmission Modes II, III, IV as described above are also specified in the standard. The MSC 4 comprises one or more Common Interleaved Frames (CIF) 5. The mode I DAB frame of Figure 1 has the MSC divided into four CIFs. Within the MSC, the basic addressable unit is the Capacity Unit (CU) representing 64 data bits. Each CIF holds 864 CUs. CU addresses are specified from 0 to 863. If the location of the first symbol in the DAB frame (i.e. the null symbol) is given the index 0, the location of the first MSC symbol for each mode is given in the table below.

DAB mode	Symbols per frame	Number of FICsymbols	Index of first MSC symbol	CIFs per frame	CUs per symbol
I	77	3	5	4	48
II	77	3	5	1	12
III	154	8	10	1	6
IV	77	3	5	2	24

[0018] For each audio or data service carried by the DAB frame within the MSC, the data is distributed in consecutive CUs (positioned in successive symbols within the same CIF). In modes I and IV, there is more than one CIF per frame, and the data for a particular service is contained in successive symbol bursts with no interleave. Consequently, CUs belonging to a particular audio or data service occur in 4 or 2 bursts within mode I and IV frames respectively. Figure

1 shows a selected sub-channel appearing in the first CIF, and the subsequent bursts relating to the same sub-channel, which occur in the remaining three CIFs.

[0019] In accordance with a preferred embodiment of the invention, where a particular sub-channel is selected, the tuner of the radio receiver is only powered during the time periods necessary to ensure reception of the selected sub-channel. The power supply to the tuner may be switched off during portions of the frame containing symbols relating to other sub-channels, resulting in a power saving.

[0020] Figure 1 shows all the symbols which must be demodulated in order to allow the full decoding of a selected sub-channel. These are the NULL, SYNC and FIC symbols, the MSC symbols occupied by the selected sub-channel, and any OFDM symbol preceding a selected MSC symbol where differential (DQPSK) encoding is used. In addition, the tuner may be switched on before the beginning of a required symbol, to allow for the transient settling period of the tuner. Such a "guard period" may also be employed before the tuner is switched off at the end of a symbol, to avoid the loss of data.

[0021] In the example shown in Figure 1, assuming the turn-on transient-settling period is negligibly small, the RF tuner is only switched on for 29 symbols out of 77 in the frame, ie. a 62% power reduction compared to being continuously powered.

[0022] The start and end CU addresses of any given DAB sub-channel are specified in the FIC. These addresses can be changed dynamically under the procedures for multiplex reconfiguration given in the EBU standard, such that a given sub-channel will not always appear at the same location in different frames. Typically, a DAB broadcast changes its configuration a few times everyday.

[0023] The FIC is structured such that it contains separate CU address information for each CIF within the DAB frame. In order to effectively control the supply of power to the tuner in response to this information, it is therefore necessary to determine which symbols in the overall DAB frame correspond to a particular CU address within a given CIF.

[0024] Using the mode I DAB frame of Figure 1 as an example, the frame is made up of 77 symbols (numbered 0 to 76), comprising a NULL symbol, a SYNC symbol, three FIC symbols and four consecutive CIFs, each 18 symbols in length.

[0025] The FIC may specify that a particular sub-channel is located at, for example, CU addresses 100 to 319 of the first CIF in the frame, and also at CU addresses 100 to 319 in each of the three other CIFs respectively. This information can then be converted into power on times for the tuner, as follows.

[0026] The first five symbols of the mode I DAB frame (symbols 0-4) comprise the NULL, SYNC, and FIC symbols, as stated previously, and the tuner must be powered during this period. The first symbol of the first CIF is therefore the sixth symbol of the DAB frame (symbol number 5). Since there are 18 symbols in each CIF, and each symbol comprises 48 CUs, the first CIF contains 864 CUs located at symbols 5-22 of the DAB frame. Symbol 5 of the frame therefore corresponds to CU addresses 0 to 47 of the first CIF, symbol 6 corresponds to CU addresses 48 to 95, and so on. Therefore, the symbols relating to the given sub-channel in the first CIF are symbols 7 to 11, since these correspond to CU addresses 96 to 335 within the first CIF.

[0027] The second CIF occupies symbols 23 to 40 of the DAB frame, the third CIF occupies symbols 41-58, and the fourth CIF occupies symbols 59 to 76. Therefore, using the same principles as for the first CIF, CU addresses 100 to 319 within each of these CIFs correspond to symbols 25-29, 43-47 and 61-65, respectively, within the DAB frame.

[0028] Thus, where the selected sub-channel occupies CU addresses 100-319 of each CIF in a mode I DAB frame, it can be seen that the tuner must be powered to receive symbols 0-4, 7-11, 25-29, 43-47 and 61-65 within the frame. As shown in Figure 1, the symbol preceding each block of required symbols must also be received where differential encoding is employed. In this example, these extra symbols are numbers 6, 24, 42 and 60. Therefore a total of 29 out of the 77 symbols of each frame are required in this particular example, although this may vary greatly depending on the size of the sub-channel and the DAB mode used.

[0029] Following from the example above, the formulae to determine the symbol location holding a particular CU are given below for each of the four DAB transmission modes. (Null symbol has index 0. CU address is denoted by C.)

Mode I

[0030] As there are four CIFs, the CU address within a CIF maps to four symbols, depending on which CIF is referred to:

$C/48+5$, $C/48+23$, $C/48+41$ and $C/48+59$

Mode II

[0031] The CU address maps to only one symbol: $C/12+5$

Mode III

[0032] The CU address maps to only one symbol: C/6+10

Mode IV

[0033] The CU address maps to two symbols: C/24+5 and C/24+41

[0034] Using the above formulae, the symbols containing the CUs belonging to any selected sub-channel can be determined. As the QPSK symbols are differentially coded, the symbol preceding the one containing the start CU must also be demodulated.

[0035] The architecture of a DAB receiver is shown schematically in Figure 2, and has been described previously. In the receiver according to an embodiment of the invention, the system controller includes means for controlling the supply of power to the tuner in response to the contents of the FIC. The functional blocks in Figure 2 for processing the signal received by the tuner (analogue-to-digital converter, FFT processor, etc.) may be integrated as software within a single component.

[0036] The power supply to the external tuner may be controlled by a signal that is approximately synchronous to the symbol rate of the DAB transmission (allowing for any guard period), particularly where the system controller is an external component. Alternatively, where an on-chip system controller is used, a pin should be reserved to bring out this signal. A programmable register may also be used to allow for different switch-on transient times for different RF tuners. During the off periods of the control signal, the RF tuner may be partially or completely powered down. By modulating the power supply to the RF tuner, the overall power consumption of the DAB receiver can be reduced.

[0037] In a preferred embodiment, a significant power saving can be achieved through the use of such a control signal to turn off the tuner alone. Similar signals could be provided to control the power supply to each functional block, thereby providing greater savings. However, the power reduction achieved by the use of such further signals is less significant, for a number of reasons. Firstly, the power reduction benefit is marginal for the extra complexity; secondly, alternative power saving techniques, such as the use of a lower clock rate, may be employed; and finally, separate control signals are not required where the various functions are integrated as software into the same unit.

[0038] The realisable power-saving is greatest when part of the multiplex is not required by the user. In DAB modes II, III and IV the proportion of time spent on the FIC and transient-settling period is greater, and the power saving benefit is somewhat reduced.

[0039] It is desirable for the RF tuner to be able to recover from complete power-down in the shortest time possible in a power-efficient manner. Partial power-down and longer switch-on transient times will reduce the power saving.

[0040] Embodiments of the invention may be employed in various applications, examples of which are given below:

1. A receiver stand-by mode that monitors the FIC and possibly one small data sub-channel. In this mode the receiver would operate similarly to a pager.
2. Portable receivers for audio information only that never or seldom require all symbols to be demodulated.

Claims

1. A method for reducing the power consumption of a radio receiver comprising a tuner for receiving a modulated signal and means for demodulating the received signal, the signal being transmitted in the form of transmission frames, each frame comprising a data portion and a configuration portion which contains information regarding the location of data within the data portion,

   wherein power is supplied to the tuner to allow reception of the configuration portion of each frame, and the supply of power to the tuner is modulated in response to the information contained in the configuration portion to enable reception of selected data within the data portion of the frame.

2. A method according to claim 1, wherein the tuner is completely or partially powered down during at least a part of the data portion which does not contain selected data, and full power is supplied to the tuner during the remainder of each frame.

3. A method according to claim 2, wherein the tuner is fully powered to allow demodulation only of the configuration portion and selected parts of the data portion.

4. A method according to claim 2 or 3, wherein full power is additionally supplied to the tuner for a predetermined period immediately preceding and/or following portions of the frame containing the selected data.

5. A method according to any of claims 2 to 4, wherein the selected data corresponds to a selected audio and/or data service.

6. A method according to claim 5, wherein the service is selected by the user.

7. A method according to any of claims 2 to 6, wherein the configuration portion includes a synchronisation portion.

8. A method according to any of claims 2 to 7, wherein the tuner is fully powered for a discrete time interval following the configuration portion of the frame.

9. A method according to any of claims 2 to 8, wherein the tuner is fully powered for a plurality of discrete time intervals following the configuration portion of the frame.

10. A method according to claim 8 or 9, wherein the duration and/or start time of the discrete time interval(s) is/are variable.

11. A method according to claim 10, wherein the duration and/or start time of the discrete time interval(s) is/are variable in response to the information contained in the configuration portion of the frame.

12. A method according to any of claims 2 to 11, wherein each transmission frame comprises a series of Orthogonal Frequency Division Multiplex (OFDM) symbols.

13. A method according to claim 12, wherein the configuration portion comprises a NULL symbol, a Phase Reference (SYNC) symbol and directory symbols which contain information regarding the location of data within the data portion.

14. A method according to claim 12 or 13, wherein the tuner is fully powered to allow demodulation only of the NULL symbol, Phase Reference (SYNC) symbol, directory symbols, symbols containing selected data and the symbol preceding each symbol or group of symbols containing selected data.

15. A radio receiver for receiving a modulated signal transmitted in the form of transmission frames, each frame comprising a data portion and a configuration portion which contains information regarding the location of data within the data portion, the receiver comprising:

a tuner for receiving the modulated signal,
means for demodulating the received signal,
means for supplying power to the tuner to allow reception of the configuration portion of each frame, and
means for modulating the supply of power to the tuner in response to the information contained in the configuration portion of each frame, to enable reception of selected data within the data portion of the frame.

16. A radio receiver according to claim 15, comprising means for completely or partially powering down the tuner during at least a part of the data portion which does not contain selected data, and supplying full power to the tuner during the remainder of each frame.

17. A radio receiver according to claim 16, comprising means for supplying full power to the tuner during one or more discrete time intervals following the configuration portion of the frame.

18. A radio receiver according to claim 17, comprising means for varying the duration(s) and/or start time(s) of the discrete time interval(s).

19. A radio receiver according to claim 18, wherein the means for varying the duration(s) and/or start time(s) are responsive to the information contained in the configuration portion of the frame.

20. A radio receiver according to any of claims 15 to 19, comprising means for generating a control signal for modulating the supply of power to the tuner.

21. A radio receiver according to any of claims 15 to 20, wherein the modulated signal is a Digital Audio Broadcast signal.

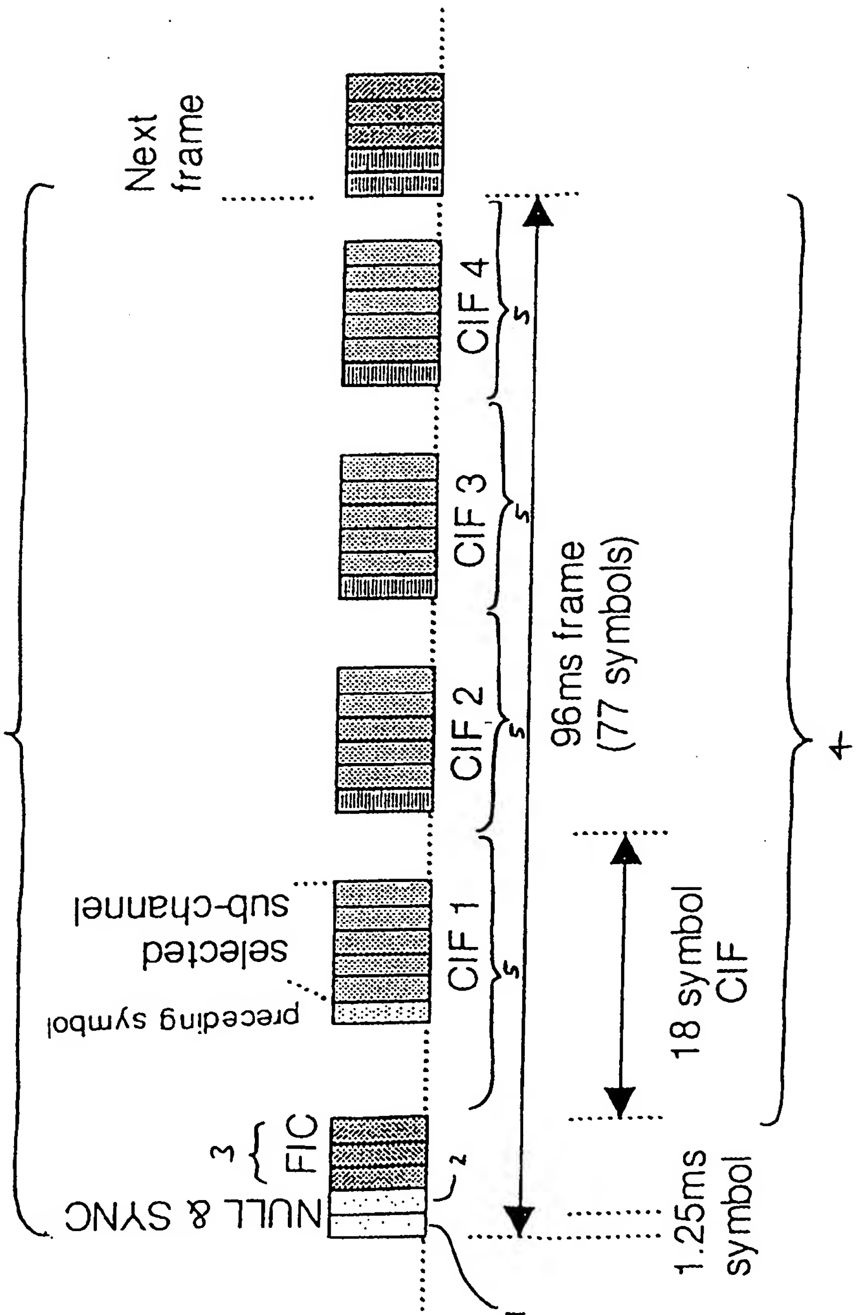
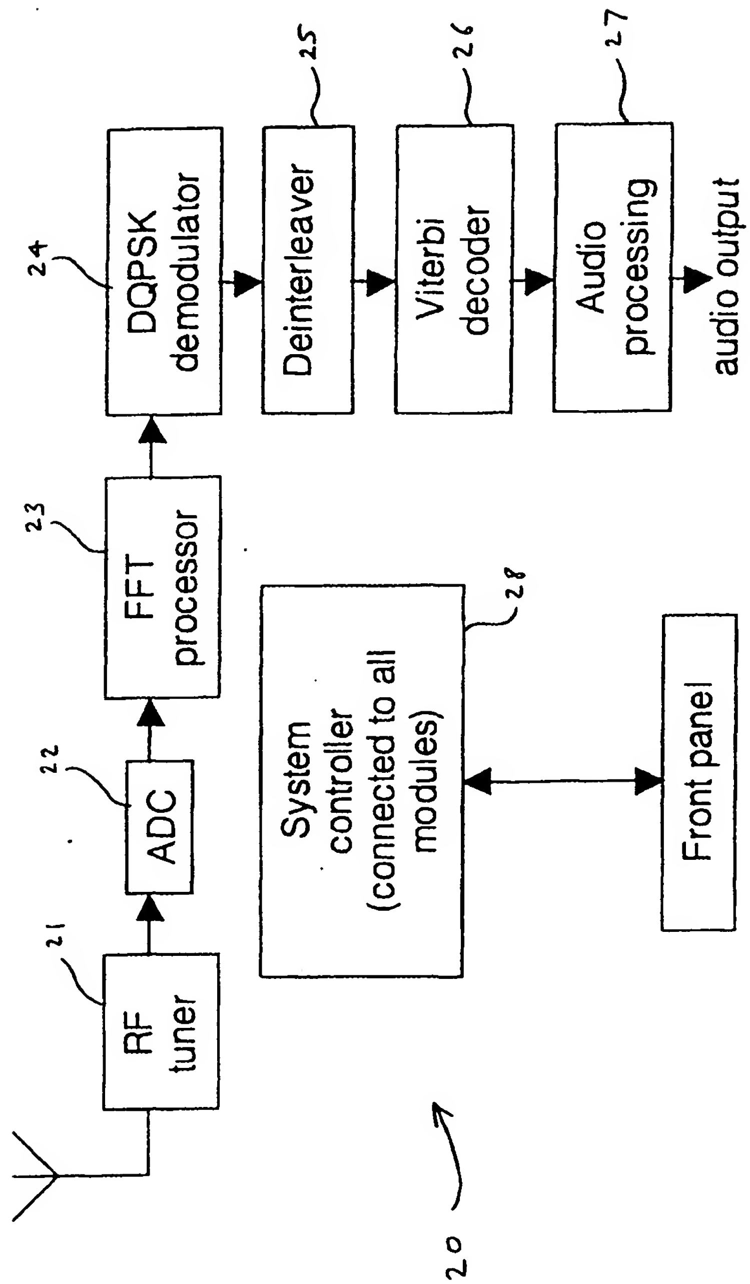

NULL & SYNC
FIC
preceding symbol
selected
sub-channel
CIF 1
CIF 2
CIF 3
CIF 4
Next
frame
96ms frame
(77 symbols)
18 symbol
CIF
1.25ms
symbol
10
3
2
5
4
1

FIG. 1

FIG. 2


RF tuner
21
ADC
22
FFT processor
23
DQPSK demodulator
24
Deinterleaver
25
Viterbi decoder
26
Audio processing
27
audio output
System controller (connected to all modules)
28
Front panel
20

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 30 5867

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X A	WO 99 31811 A (RAMASWAMY KUMAR ;KNUTSON PAUL GOTHARD (US); THOMSON CONSUMER ELECT) 24 June 1999 (1999-06-24) * abstract * * page 2, line 1 - line 16 * * page 5, line 6 - page 6, line 23 *	1-3,5,7,8,15-17,20 4,6,9-12,18,19,21	H04B1/16 H04H1/00
A	HUISKEN ET AL: "A power-efficient single-chip OFDM demodulator and channel decoder for multimedia broadcasting" 1998 IEEE INTERNATIONAL SOLID-STATE CIRCUITS CONFERENCE, ISSCC, 5 - 5 February 1998, pages 40-41, XP002125499 New York, USA * the whole document *	1-21	
A	US 5 757 782 A (GASKILL GAROLD B) 26 May 1998 (1998-05-26) * abstract * * figure 5 * * column 2, line 14 - line 67 * * column 4, line 37 - column 5, line 17 * * column 6, line 54 - column 7, line 20 *	1-3,7-9,12,15-17,20	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04B H04H H04Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22 December 1999	Lindhardt, U

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 30 5867

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

22-12-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9931811 A	24-06-1999	AU 8924798 A	05-07-1999
US 5757782 A	26-05-1998	US 5537407 A	16-07-1996
		US 5159713 A	27-10-1992
		US 4713808 A	15-12-1996
		US 5309153 A	03-05-1994
		US 5629940 A	13-05-1997
		AT 61705 T	15-03-1991
		AT 151187 T	15-04-1997
		AT 149722 T	15-03-1997
		AT 149261 T	15-03-1997
		AU 2962789 A	22-06-1989
		AU 578995 B	10-11-1988
		AU 5207886 A	01-07-1986
		AU 636449 B	29-04-1993
		AU 7123091 A	16-05-1991
		CA 1260636 A	26-09-1989
		DE 3588142 D	03-04-1997
		DE 3588142 T	09-10-1997
		DE 3588144 D	10-04-1997
		DE 3588144 T	12-06-1997
		DE 3588151 D	07-05-1997
		DE 3588151 T	09-10-1997
		DK 367186 A	03-10-1986
		EP 0211849 A	04-03-1987
		EP 0413369 A	20-02-1991
		EP 0412574 A	13-02-1991
		EP 0408086 A	16-01-1991
		FI 863130 A	31-07-1986
		JP 2608257 B	07-05-1997
		JP 7303270 A	14-11-1995
		JP 2678150 B	17-11-1997
		JP 8065260 A	08-03-1996
		JP 2651127 B	10-09-1997
		JP 8046415 A	16-02-1996
		JP 7303271 A	14-11-1995
		JP 2608258 B	07-05-1997
		JP 7322322 A	08-12-1995
		JP 2608259 B	07-05-1997
		JP 8047023 A	16-02-1996
		JP 2046766 C	25-04-1996
		JP 7073379 B	02-08-1995
		JP 63158924 A	01-07-1988
		JP 2608246 B	07-05-1997
		JP 6216830 A	05-08-1994
		NO 863108 A	01-10-1986

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 30 5867

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

22-12-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5757782 A		WO 8603645 A	19-06-1986
		US 5416827 A	16-05-1995
		US 4897835 A	30-01-1992
		US 5682148 A	28-10-1997
		US 5065423 A	12-11-1991
		US 5185604 A	09-02-1993

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82